

## REVERSIBLE IMAGE DISPLAY MEDIUM

### CROSS-REFERENCE TO RELATED APPLICATION

5 [0001] This application is based on Japanese  
Patent applications No.2000-350201 and No.2000-  
350219 filed in Japan on November 16, 2000,  
respectively, the contents of which are hereby  
incorporated by reference.

### BACKGROUND OF THE INVENTION

10 1. Field of the Invention

[0002] The present invention relates to an image  
display medium, and particularly relates to a  
reversible image display medium, in which image  
displaying and image erasing operations can be  
15 repeated.

2. Description of the Background Art

[0003] At present, image display is performed,  
e.g., in the following manners. A person uses a  
pencil, a pen, paints or the like, and manually  
20 writes or draws characters, pictures or the like on  
an image display medium such as paper sheet. Also, a  
computer, a word processor or the like is used to  
display text, graphics or the like on a display such  
as a CRT display, or output them on a medium such as  
25 a paper sheet via a printer for display.

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[0004] A copying machine or the like may be used for producing duplication, on a medium of paper or the like, of the texts, pictures, graphics or the like, which are produced on the medium of paper or the like by a person or by a printer. A facsimile machine may be used for sending such contents (texts, pictures, graphics and others) prepared in the above manner for producing duplication on another medium of paper or the like.

10 [0005] The above image display, which is performed to display the texts, pictures or the like on the image display medium of paper or the like by a pencil, pen or the like, or by an image forming apparatus such as a printer, a copying machine or a  
15 facsimile machine operating in a electrophotographic method, an ink-jet method, a heat transfer method or the like, can achieve clear image display in a high resolution, and thus can achieve easy-on-the-eyes display.

20 [0006] However, it is impossible to repeat display and erasure of the images on the image display medium of paper or the like. In the case where the paper is used for writing characters or the like by a pencil, the characters can be erased by an eraser  
25 to a certain extent. However, it is difficult to

erase completely the characters or the like written in an ordinary density, although it may be possible when written in a light density. The medium of paper or the like can not be reused except for the case of using the rear surface of the medium, which is not yet used for the image display.

[0007] Accordingly, the medium of paper or the like bearing images will be abandoned or burnt when it is not longer required. This results in consumption of a large mount of resources. The printer, copying machine or the like also consume consumable products or materials such as toner or ink. For obtaining the new display medium of paper or the like as well as toner, ink or the like, energies and resources are required for producing them. This is contrary to the current demand for reduction in environmental loads.

[0008] In contrast to the above, the image display by a display such as a CRT display can repeat the image display and the image erasure. However, the resolution, clarity and precision of images are restricted, as compared with the images displayed by the printer or the like on the paper medium or the like. Thus the image display by a display is improper especially when used for displaying the

text documents mainly composed of letters because of low resolution. If it is used for displaying sentences which continue in less than the frame-size volume, it will do. However, if the sentences  
5 continue in twice or more times the frame-size volume, they may be difficult to read and to understand. Due to the relatively low resolution and the light emission from the display, operations for a long time are likely to be hard to eyes.

10 **[0009]** Electrophoretic display (EPD) and Twist ball-type display (TBD) have been proposed as an image display method allowing repetition of the image display and image erasure. Further displaying method was recently proposed, which is disclosed in  
15 "Japan Hardcopy '99, the book of the thesis, pp. 249-252".

**[0010]** In the electrophoretic display method, two substrates including at least one transparent substrate are opposed together with a spacer  
20 therebetween to form a closed space therebetween, and the space is filled with a display liquid formed of a dispersion medium and electrophoretic particles, which are dispersed in the dispersion medium and are different in color from the medium. The image  
25 display is performed by an application of an

electrostatic field and in a color of the particles  
or a color of the dispersion medium.

[0011] The display liquid is usually formed of  
isoparaffin-contained dispersion medium, particles  
5 of titanium dioxide or the like, dyes applying  
contrast in color to the particles, and an additive  
such as a surface active agent, or a charge applying  
agent.

[0012] In the electrophoretic display, the display  
10 is performed by utilizing contrast between particles  
of a high refractive index (e.g., titanium dioxide  
particles) and colored insulating liquid, and  
therefore the particles can not hide the colored  
liquid to a high extent, resulting in a low contrast.

[0013] Furthermore, there is a limitation on the  
15 kind of dye which is dissolved in a high  
concentration in a nonpolar solvent of high  
resistance which allows the electrophoresis of  
particles. A dye showing a white color is not found.  
20 Nor known is a black dye having a high extinction  
coefficient. Therefore the background portion  
becomes colored so that it is difficult to achieve a  
good contrast by a white background. When white  
particles for formation of images are placed into a  
25 colored liquid, the colored liquid may be moved

between the substrate and the layer of white particles which are moved to the image observation side substrate, or the colored liquid may come into between the white particles, thereby lowering the contrast. The electrophoretic particles can scarcely uniformly adhere to the image observation side substrate, and thus the resolution is low.

[0014] Further, settling and condensation of particles are liable to occur due to a very large difference in specific gravity between the particles and the dispersion medium in the display liquid. This is liable to lower the display contrast. Further, it is difficult to display the images with high stability for a long time, and remaining of last images is liable to occur. Further, the degree of charging of the particles in the liquid significantly changes with time, which also impairs the stability of the image display.

[0015] In the twist ball-type display method, images can be displayed in specified colors using an image display medium containing numerous microcapsules enclosing not only an insulating liquid but also fine spheric particle so processed that a half of their surface and the other surface portion show colors or an optical density which

differs from each other. Images are displayed in predetermined colors by rotating the fine spherical particles in the microcapsules due to an electric field strength or magnetic strength.

5 [0016] However, according to the twist ball-type display, images are displayed using fine spherical particles in the insulating liquid within the microcapsules. This makes it difficult to attain good contrast. Further, the resolution is low since  
10 spaces are formed between the microcapsules. In the manufacture of microcapsules, difficulty is entailed in reducing the size of microcapsules to increase the resolution.

[0017] The "Japan Hardcopy '99, the book of the  
15 thesis, pp. 249-252" discloses an image displaying method wherein a closed space is formed by placing two substrates as opposed to each other and as spaced from each other, i.e. the two substrates being a laminate of electrodes and a charge  
20 transporting layer, the space being used to enclose the electrically conductive toner and insulating particles which are different in color from the toner, an electrostatic field being applied to inject charges into the electrically conductive  
25 toner so that the toner is moved by a Coulomb force





such as developers and ink so that a current demand for reduction in environmental loads can be satisfied.

[0020] Another object of the invention is to  
5 provide a reversible image display medium, which allows image display in good contrast and high quality.

[0021] Still another object of the invention is to  
10 provide a reversible image display medium, which allows image display in high resolution and high quality, and more specifically, in high resolution as compared with the electrophoretic display and the twist ball-type display, and also in higher resolution when image display is performed based on  
15 an electrostatic latent image without employing opposite electrodes.

[0022] Yet another object of the invention is to  
provide a reversible image display medium, which allows stable image display of high quality for a  
20 long time.

[0023] Further another object of the invention is to provide a reversible image display medium, which can suppress remaining of last image(s), and therefore can exhibit good reversibility so that an  
25 image of good quality can be displayed.

[0024] Further another object of the invention is to provide a reversible image display medium, which can reduce a drive voltage required for image display.

5 [0025] A further object of the invention is to provide a reversible image display medium, which allows quick image display.

[0026] The present invention relates to a reversible image display medium, which basically has  
10 the following structure.

[0027] The reversible image display medium comprises:

two substrates opposed to each other with a predetermined gap therebetween;

15 one or more developer accommodating cells formed between the two substrates, and each having a periphery surrounded by a partition wall; and

a dry developer contained in each of the cell(s),  
the dry developer containing at least two kinds of  
20 frictionally chargeable dry developing particles having different chargeable polarities and different optical reflection densities.

[0028] The invention provides reversible image display mediums having such basic structure and the  
25 following features.

(1) First reversible image display medium

[0029] This reversible image display medium has the following feature: on one of the two substrates in the medium, an electrostatic latent image  
5 corresponding to an image to be displayed is formed so that image display can be performed by driving the developing particles in an electric field based on the electrostatic latent image. A surface, which faces the developing particles, of the substrate for  
10 carrying the electrostatic latent image has a surface resistivity of at least  $1 \times 10^{12}$  ohm/square ( $\Omega/\square$ ).

(2) Second reversible image display medium

[0030] This reversible image display medium has  
15 the following feature: on one of the two substrates, an electrostatic latent image corresponding to an image to be displayed is formed so that image display can be performed by driving the developing particles in an electric field based on the  
20 electrostatic latent image. A surface, which faces the developing particles, of the substrate opposed to the substrate for carrying the electrostatic latent image has a surface resistivity in a range of from  $1 \times 10^6$  ohm/square ( $\Omega/\square$ ) to  $1 \times 10^{12}$  ohm/square  
25 ( $\Omega/\square$ ).



shown in Fig.1 on which images are displayed.

[0037] Fig.3 is a perspective view showing a first substrate and a grid-like partition member formed thereon in the medium shown in Fig.1.

5 [0038] Fig.4 is a plan view showing the first substrate and independent electrodes formed thereon in the medium shown in Fig.1.

[0039] Fig.5 is a view showing an example of the image display on the medium shown in Fig.1.

10 [0040] Fig.6(A) is a sectional view showing another example of the reversible image display medium. Fig.6(B) is a sectional view showing a further example of the reversible image display medium.

15 [0041] Fig.7(A) and Fig.7(B) show other example of the reversible image display medium. Fig.7(A) is a sectional view of the reversible image display medium before image display. Fig.7(B) is a sectional view of an example of the medium in image display.

20 [0042] Fig.8(A) and Fig.8(B) show further example of the reversible image display medium. Fig.8(A) is a sectional view of the reversible image display medium before image display. Fig.8(B) is a sectional view of an example of the medium in image display.

25 [0043] Fig.9 is a plan view showing the medium

shown in Fig.8(A) and Fig.8(B) as partly cut away.

[0044] Fig.10(A) is a sectional view showing another example of the reversible image display medium. Fig.10(B) is a sectional view showing a further example of the reversible image display medium.

[0045] Fig.11 is a view schematically showing an example of an image forming apparatus having an external electrostatic latent image forming device.

10 [0046] Fig.12(A) and Fig.12(B) show a schematic view showing the structure of an example of an image forming apparatus having an ion flow type direct electrostatic latent image forming device.

[0047] Fig.13 is a schematic view showing the structure of an example of an image forming apparatus having a multi-stylus type direct electrostatic latent image forming device.

15 [0048] Fig.14 is a schematic view showing the structure of an example of an image forming apparatus having a multi-stylus type direct electrostatic latent image forming device provided with neighboring control electrodes.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0049] A reversible (in other words, reusable)  
25 image display medium according to a preferred



developing particles are employed) or the like may be formed so that the image can be erased. Also, the image can be rewritten by forming a different electrostatic field. Accordingly, it is not

5 necessary to abandon the image display medium, on which the image is already displayed. The developing particles are contained in the cell, and therefore external supply or addition of the developer is not required. Owing to these facts, it is possible to

10 reduce remarkably the use of the image display medium such as paper sheets as well as consumable materials such as developer in the prior art. In contrast to the image formation of the electrophotographic type or the like in the prior

15 art, it is not necessary to melt the toner for fixing it onto a sheet of paper or the like, and a majority of the image forming energy, which is required in such an image forming apparatus in the prior art, is not required.

20 [0053] Owing to the above features, the medium can satisfy a current demand for reduction in environmental loads.

[0054] The developer contained in the cell includes at least two kinds of developing particles

25 having different optical reflective densities, and



in other words, exhibiting different contrasts or different colors. Further, the developing particles are dry particles, and one kind of the developing particles can appropriately screen or hide the other  
5 kind of developing particles. Therefore, image display in good contrast can be achieved.

[0055] The developer contained in the cell includes at least two kinds of the chargeable dry developing particles, which can be frictionally  
10 charged to have different chargeable polarities. For image display, the developing particles which are mutually reversely charged by the frictional charging are easily moved by the Coulomb force. This also achieves the display in good contrast, and can  
15 suppress remaining of the last image, and also allows quick display of images, and further can reduce a drive voltage required for image display.

[0056] The dry developing particles can suppress settling and condensation as compared with, e.g.,  
20 electrophoretic particles in a display liquid used for electrophoretic image display, because the liquid is not present. This also suppress lowering of the contrast of the image display, and thereby can perform stable image display for a long time.  
25 Since the settling and condensation of the



potential on the substrate, which is opposite to the substrate for carrying the electrostatic latent image. This predetermined potential can be placed by applying the bias voltage to the above opposite  
5 substrate, or grounding the opposite substrate, simultaneously with formation of the electrostatic latent image, or after formation of the electrostatic latent image.

[0060] Materials useful for substrates and cell  
10 partition walls can be selected from a wide range. Useful substrates include, for example, glass substrates, hard or soft synthetic resin substrates, and soft film substrates.

[0061] At least one of the two substrates forming  
15 the medium (arranged on the image observation side) is light permeable to allow seeing the displayed image.

[0062] In the case of forming an electrostatic  
latent image for image display on the medium surface,  
20 the substrate for carrying the electrostatic latent image can be formed of an insulating substrate. The other substrate on the opposite side (e.g., on the non-observation side) may be an insulating substrate or another kind of substrate. If the other substrate  
25 is an insulating substrate and ground potential or a



the electrostatic latent image makes it difficult to hold the latent image on the substrate and causes disturbance of images such as image deletion and image blurring.

5 [0064] Therefore, the developer-facing surface (surface facing the developing particles) of the substrate for carrying the electrostatic latent image may have a surface resistivity of  $1 \times 10^{12}$  ohm/square ( $\Omega/\square$ ) or more to retain the latent image  
10 in the desired degree which results in display of high quality image. An upper limit of the surface resistivity is not restricted but is presumably approximately  $1 \times 10^{16}$  ohm/square ( $\Omega/\square$ ) in view of the substrate commercially available, although not  
15 confined thereto.

[0065] If the developer-facing surface of the substrate opposed to the substrate for carrying the electrostatic latent has an excessively high surface resistivity in image display by forming the  
20 electrostatic latent image, it becomes difficult to conduct electrostatic shielding relating to the substrate when image display mediums are overlapped after image display, or in other words, images become easily affected by charges such as the  
25 charges on the medium overlapped, resulting in

likelihood of collapsing of images and in difficulty  
in stably holding the images. Further in this case,  
it becomes difficult to remove the charges of the  
electrostatic latent image in erasing or rewriting  
5 the images, making it likely to cause remaining of  
last images. On the other hand, if the developer-  
facing surface of the substrate opposed to the  
substrate for carrying the electrostatic latent  
image has an excessively low surface resistivity,  
10 discharge tends to occur between the two substrates,  
resulting in failure to obtain a uniform electric  
field for image display and in tendency of giving  
rise to image irregularity.

[0066] The displayed image can be stably held if  
15 the surface resistivity in the range of from  $1 \times 10^6$   
ohm/square ( $\Omega/\square$ ) to  $1 \times 10^{12}$  ohm/square ( $\Omega/\square$ ) is  
shown by the developer-facing surface of the  
substrate opposed to the substrate for carrying the  
electrostatic latent image. In this case, remaining  
20 of last image and image irregularity are suppressed,  
and high quality images can be displayed.

[0067] Regardless of whether image display is  
performed based on an electrostatic latent image or  
not, if the developer-facing surface of the  
25 substrate has an excessively low surface roughness,



excessively low surface roughness, the light quantity of regular reflection (gloss) becomes large when the displayed images are seen and the images can not be clearly seen. If the surface of the substrate has an excessively high surface roughness, the quantity of scattered light is increased when seeing the images and the substrate is reduced in light permeability. Thereby the displayed images become opaque as a whole and suffer a lowered contrast.

[0070] In view of this problem, the external surface of at least the substrate on the image observation side, among the substrates forming the medium, may have a surface average median roughness  $R_a$  of 0.2  $\mu\text{m}$  to 0.7  $\mu\text{m}$ , resulting, when seen, in controlled light quantity of regular reflection (gloss) and suppressed scattering of light, and in displayed image in good contrast which can be easily seen.

[0071] There is no limitation on the number, size, shape, distribution, arrangement (regular or irregular) and others of the developer-accommodating cells insofar as the image is displayed. Optionally a developer-moving suppressing member and a spacer for maintaining a gap between the substrates may be



provided between the substrates. The cell partition wall may serve as the developer-moving suppressing member and the spacer.

[0072] For example, when an electrostatic latent  
5 image is formed on the substrate, an excessively large gap between the substrates or an excessively large thickness of each substrate reduces the electric field applied to the developer between the substrates, and therefore impairs the development  
10 performance so that the contrast is lowered. If the gap between the substrates is excessively small, this reduces an amount of the developer, which can be accommodated in the developer accommodating cell, so that required contrast can not be achieved. If  
15 the thickness of each substrate is excessively small, and therefore the whole thickness of the medium affected by the thickness of each substrate is excessively small, the medium is liable to be curved so that the gap between the substrates can not be  
20 uniform, and the image irregularities are liable to occur. Accordingly, it is preferable that each substrate has a thickness from 5  $\mu\text{m}$  to 100  $\mu\text{m}$ , the gap between the opposite substrates is in a range from 20  $\mu\text{m}$  to 300  $\mu\text{m}$ , and the whole thickness is in  
25 a range from 30  $\mu\text{m}$  to 500  $\mu\text{m}$ , although not

restricted to these values.

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[0073] The developing particles may be frictionally charged by applying mechanical vibrations after accommodating the developing particles in the cells, or by frictionally charging at least two kinds of developing particles by stirring and then accommodating the developing particles in the cells. The latter method is preferable to give the developing particles frictionally charged in the desired state. At any rate, the developing particles are frictionally charged before image display.

[0074] Such reversible image display medium may have or may not have electrodes. If the substrate is free of electrode, the medium can be so simplified and the use of an elastic substrate such as a film is easily allowed.

[0075] Useful reversible image display mediums with electrodes include, for example, those in which an electrode (preferably transparent electrode) is formed on the internal surface of one of substrates which is permeable to light while an electrode opposed to the electrode is formed on the internal surface of the other substrate.

[0076] The electrode formed on the internal



such non-conductive particles allows easy and reliable charging by friction of the two kinds of developing particles, regardless of whether the image display medium has the electrodes or not.

5 Thereby, the image display can be further improved.

[0080] Of the two kinds of developing particles forming the dry developer, at least one kind of the developing particles may be magnetic particles. The existence of such magnetic particles allows

10 affecting a magnetic stirring force on the developer (developing particles) by the magnetic field (e.g., oscillating magnetic field) in relation to driving the developing particles in the electrostatic field.

Owing to the stirring of the developer, the  
15 developing particles can easily move in the electrostatic field for image display. Thereby, the contrast is further improved and the required voltage for image display can be further lowered.

[0081] In other words, regardless of whether the  
20 image display medium has the electrodes or not, the existence of such magnetic particles allows stirring the developer (developing particles) by the magnetic field (e.g., oscillating magnetic field). Owing to the stirring of the developer, the developing  
25 particles can easily move when initializing the

medium or erasing the last image, or displaying the new image in the electrostatic field for image display. Thereby, the image display is further improved.

5 [0082] The developing particles may be stirred by applying AC voltage or like alternating voltage and/or applying mechanical vibrations. Optionally the stirring may be done using a combination of two or more stirring means such as alternating voltage  
10 agitation, magnetic agitation, mechanical agitation, ultrasonic wave emission and the like.

[0083] One kind of the developing particles may be nonconductive and magnetic particles.

[0084] In any one of the foregoing cases, if the  
15 developing particles are excessively small, they have an excessively large adhesiveness, and therefore cause mutual adhesion of the particles and reduction in developing efficiency. Further, such excessively small developing particles carry a large  
20 amount of charges so that a large electric field is required for moving the particles for image display, and therefore, a high drive voltage is required.

[0085] If the developing particles are excessively large, the frictional charging can not be performed  
25 in an intended manner so that the developing

particle moving speed can not be increased sufficiently in the electrostatic field for image display, and/or good contrast can not be achieved.

[0086] In view of the above as well as the

5 material and others for obtaining the predetermined characteristics of the developing particles, the appropriate particle diameter (volume average particle diameter) of the non-conductive developing particle is in a range from 1  $\mu\text{m}$  to 50  $\mu\text{m}$ , and the  
10 appropriate particle diameter (volume average particle diameter) of the magnetic developing particle is in a range from 1  $\mu\text{m}$  to 100  $\mu\text{m}$ .

[0087] The developing particles can be formed, for example, from a binder resin and a coloring agent,  
15 etc. or with a coloring agent alone, etc. Those which are usable are described below.

Binder resin

[0088] The binder resin is not specifically limited in so far as it can disperse a coloring  
20 agent, magnetic substance, etc. and is usable usually as a binding agent. Binding resins which are usable for electrophotography toner are used as a representative example.

[0089] Examples of useful binder resins are  
25 polystyrene type resins, poly(meth)acrylic type

resins, polyolefin type resins, polyamide type  
resins, polycarbonate type resins, polyether type  
resins, polysulfone type resins, polyester type  
resins, epoxy resins, urea resins, urethane resins,  
5 fluorine-containing resins, silicone resins and  
copolymers, block polymers, graft-polymers and  
polymer blend, etc. of these resins.

[0090] The binder resin may have a considerably  
high glass transition temperature (T<sub>g</sub>) and need not  
10 be a thermoplastic resin.

#### Coloring agents

[0091] As the coloring agents, the following  
various kinds of organic or inorganic pigments and  
dyestuffs having various colors are usable.

15 [0092] Examples of black pigments are carbon black,  
copper oxide, manganese dioxide, Aniline Black and  
activated carbon, etc.

[0093] Examples of yellow pigments are chrome  
yellow, zinc yellow, cadmium yellow, yellow iron  
20 oxide, mineral Fast Yellow, Nickel Titanium Yellow,  
Naphthol Yellow S, Hansa Yellow G, Hansa Yellow 10G,  
Benzidine Yellow G, Benzidine Yellow GR, Quinoline  
Yellow Lake, Permanent Yellow NCG and Tartrazine  
Lake, etc.

25 [0094] Examples of orange pigments are red chrome

yellow, molybdenum orange, Permanent Orange GTR,  
Pyrazolone Orange, Vulcan Orange, Indanthrene  
Brilliant Orange RK, Benzidine Orange G and  
Indanthrene Brilliant Orange GK, etc.

- 5 [0095] Examples of red pigments are red iron oxide,  
cadmium red, red lead, mercury sulfide, Permanent  
Red 4R, Lithol Red, Pyrazolone Red, Watchung Red,  
Lake Red D, Brilliant Carmine 6B, eosine lake,  
Rhodamine Lake B, alizarin lake and Brilliant  
10 Carmine 3B, etc.

[0096] Examples of violet pigments are manganese  
violet, Fast Violet B and Methyl Violet Lake, etc.

- [0097] Examples of blue pigments are prussian blue,  
cobalt blue, Alkali Blue Lake, Victoria Blue Lake,  
15 Phthalocyanine Blue, Phthalocyanine Blue containing  
no metal, partially chlorinated Phthalocyanine Blue,  
Fast Sky Blue and Indanthrene Blue BC, etc.

[0098] Examples of green pigments are chrome green,  
chromium oxide, Pigment Green B, Malachite Green

- 20 Lake and Final Yellow Green G, etc.

[0099] Examples of white pigments are zinc white,  
titanium oxide, antimony white and zinc sulfide, etc.

- [0100] Examples of extender pigments are barite  
powder, barium carbonate, clay, silica, white carbon,  
25 talc and alumina white, etc.



[0101] Examples of various kinds of dyestuffs such as basic, acid, disperse and substantive dye are Nigrosine, Methylene Blue, Rose Bengale, Quinoline Yellow and Ultramarine Blue, etc.

5 [0102] These coloring agents are usable alone or in combination of plural of them.

[0103] Especially in white-black display, carbon black is preferable as a black coloring agent and titanium dioxide as a white coloring agent.

10 [0104] Especially in the case of preparing developing particles from a mixture of a white pigment and a meltable binding resin(binder resin), it is preferable to use the white pigment in an amount of at least 10 parts by weight, more  
15 preferably at least 20 parts by weight, per 100 parts by weight of raw monomer of white particles, in order to obtain sufficient whiteness. It is desirable to use the white pigment in an amount of up to 60 parts by weight, more preferably up to 50  
20 parts by weight, in order to secure sufficient dispersibility of the white pigment. Over 60 parts by weight of the white pigment, the binding of the pigment and the binding resin will decrease and the dispersion of the pigment will deteriorate. Less  
25 than 10 parts by weight of the white pigment, the

developing particles having a different color will not sufficiently be shaded by the pigment.

[0105] Although carbon black is preferable as the black coloring agent, it is possible to use magnetic particles or magnetic fine powder such as magnetite, ferrite, etc. as the coloring agent in order to provide magnetic character to the developing particles.

#### Other Additives

[0106] Examples of additives preferably usable other than the above binder resin or coloring agent are magnetic substance, charge-controlling agent, resistance adjusting agent, etc.

#### Charge-Controlling Agent

[0107] The charge-controlling agent is not specifically limited in so far as it provides a charge to the developing particles by friction-charging.

[0108] Examples of plus-charge-controlling agents are Nigrosine dye, triphenylmethane compound, quaternary ammonium salt compound, polyamine resin, imidazole derivative, etc.

[0109] Examples of minus-charge-controlling agents are salicylic acid-metal complex, metal-containing azo dye, metal-containing oil-soluble dye (including

metal ion or metal atom), quaternary ammonium salt compound, calixarene compound, boron-containing compound (benzilic acid-boron complex), nitroimidazole derivative, etc.

- 5 [0110] Other than the above, as charge-controlling agents are usable metal oxides such as ultrafine silica particles, ultrafine titanium oxide particles, ultrafine alumina particles, etc., nitrogen-containing cyclic compounds such as pyridine or its derivative, salt, various organic pigments, resins containing fluorine, chlorine, nitrogen, etc.

#### Magnetic substances

- [0111] Magnetic particles and magnetic fine powder are usable. Examples of these substances are
- 15 ferromagnetic elements, alloy or compounds containing the element. Examples thereof are those containing a conventionally known magnetic substance such as magnetite, hematite, ferrite or like alloys or compounds of iron, cobalt, nickel, manganese,
- 20 etc., other ferromagnetic alloy, etc. The magnetic powder may have various shapes such as particle, needle, thin flat shape, etc. and is suitably usable.

#### Resistance adjusting agent

- [0112] Resistance adjusting agents include similar
- 25 compounds to the above magnetic powder and coloring

agent.

[0113] Examples of resistance adjusting agents are metal oxides, graphite, carbon black, etc. having various shapes such as thin flat, fibrous or powder shape, etc.

[0114] Below is explained an example of preparing developing particles.

[0115] Prescribed amount of each of components selected from the above binder resin, magnetic powder, coloring agent, charge-controlling agent, resistance adjusting agent and other additives is prepared, and those components are mixed thoroughly. The mixture is further mixed with heating by use of press-kneader, twin-screw mixing device, etc. After cooling, the mixture is roughly pulverized with use of hammer mill, cutter mill, etc. and then finely pulverized with use of jet mill, angmill, etc. The resulting powder is classified by a wind classifier, etc. to a predetermined average particle size to obtain developing particles.

[0116] A developer having a predetermined amount of charges is obtained by mixing and stirring thus obtained particles having different chargeable polarities and contrasts(optical reflective densities) at a predetermined rate thereof. A third

agent such as fluidization agent may be added thereto to improve fluidity of the developer.

#### Fluidization agent

[0117] Examples of fluidity improving agents are

5 silica, alumina, titanium oxide, barium titanate, magnesium titanate, calcium titanate, strontium titanate, zinc oxide, siliceous sand, clay, mica, wallastonite, diatomaceous earth, chromium oxide, cerium oxide, red iron oxide, antimony trioxide,  
10 magnesium oxide, zirconium oxide, barium sulfate, barium carbonate, calcium carbonate, silicon carbide, silicon nitride, etc.

[0118] Particularly preferable are fine powder of silica, aluminum oxide, titanium dioxide and

15 magnesium fluoride. The fluidity improving agent is used either alone or in combination.

[0119] In the image display employing the reversible image display medium, the electrostatic field to be applied to the developing particles can  
20 be formed, for example, based on the electrostatic latent image, which is formed on, or brought close to or into contact with, e.g., the surface of one (e.g., on the image observation side) of the two substrates in accordance with the image to be  
25 displayed. The formation of the electrostatic field



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in which the electrostatic latent image charges are placed by performing the discharge to the medium surface in accordance with the image to be displayed, or of various charge injection types, in which the electrostatic latent image charges are placed by injecting charges to the medium surface in accordance with the image to be displayed. For example, the devices of the former type may be of an ion flow type, and also may be of a multi-stylus type having an electrostatic record head, in which recording electrodes are arranged in a predetermined direction (e.g., main scanning direction for substrate scanning by the device). In an example of the latter type, the device of the multi-stylus type may be used, which includes an electrostatic record head, in which the recording electrodes are arranged in a predetermined direction (e.g., main scanning direction for substrate scanning by the device), and neighboring control electrodes are arranged close to the recording electrodes.

[0122] The external electrostatic latent image forming device may be configured such that the electrostatic latent image corresponding to the image to be displayed is formed on the electrostatic latent image carrier, and then is transferred onto,

or brought close to or into contact with the substrate surface. More specifically, the electrostatic latent image corresponding to the image to be displayed may be formed, e. g., on a photoconductive member such as a photosensitive member, and may be transferred onto, or brought close to or into contact with the substrate surface. Alternatively, the electrostatic latent image corresponding to the image to be displayed may be formed on a dielectric member, and may be transferred onto, or brought close to or into contact with the substrate surface.

[0123] The image display may be performed with the electric field forming device including one of the foregoing electrostatic latent image forming devices.

[0124] By forming the electrostatic latent image on the image display medium in the foregoing transfer manner or the direct formation manner or by bringing the electrostatic latent image close to or into contact with the image display medium, the image holding properties of the medium can be improved. In particular, the image holding properties can be improved in the case of using developer having high flowability or developer having flowability which can be increased by the



developer stirring operation prior to the image display.

[0125] In the reversible image display medium having the opposite electrodes, the electrostatic field for the image display can be formed by  
5 applying a voltage across the opposite electrodes. The electrostatic field formation device for such medium will be described later.

[0126] In the reversible image display medium  
10 without an electrode or with an electrode on only one of the substrates, the electrostatic field to be applied to the developing particles can be formed, for example, by arranging an electrode or electrodes on the outer surface(s) of the medium and applying a  
15 voltage through the electrode(s).

[0127] In both the reversible image display mediums with and without the electrode, image erasing processing may be performed for erasing the previously displayed image prior to the new image  
20 display.

[0128] The image erasing processing can be performed, e.g., by forming an electric field, which can move the developing particles forming the developer in the image display medium, and/or  
25 applying a stirring force to the developer. The

application of the stirring force can be performed,  
e.g., by forming an alternating electric field,  
forming an oscillating magnetic field, emitting  
ultrasonic waves, and/or applying mechanical  
5 vibrations.

[0129] For the image display, therefore, various  
kinds of image easing devices can be appropriately  
employed. Such image erasing devices may include the  
electric field forming device for forming the  
10 electric field moving the developing particles, the  
stirring device for applying a stirring force to the  
developing particles, or both the electric field  
forming device and the stirring device.

[0130] For example, under the electric field, one  
15 kind of the developing particles, which have the  
same optical reflection density (i.e., the same  
contrast or the same color), among the two kinds of  
developing particles described above may be  
collected to one of the substrates, and the other  
20 kind of developing particles having the same optical  
reflection density may be collected to the other  
substrate. Thereby, the image erasure can be  
performed. Further, the next image formation can be  
performed by moving the developing particles on only  
25 the image portion so that the image display can be

performed smoothly and reliably in high quality.

[0131] For example, in the operation of stirring the developer (developing particles), the image is erased, and the amount of charges and the

5 flowability of the developing particles are improved. Thereby, the next image formation can be performed smoothly and reliably in a high quality.

[0132] The electric field forming device for image erasing may include a pair of electrodes (usually  
10 made of metal) or dielectric members, which are arranged on the opposite sides of the reversible image display medium, and a power supply device for applying a bias voltage across these electrodes or dielectric members.

15 [0133] In addition to the above, it is possible to employ various kinds of electric field forming devices of the discharging type, in which the electric field is formed by performing the discharging to the image display medium, and various  
20 kinds of electric field forming devices of the charge injection type, in which the electric field is formed by injecting the electric charges to the reversible image display medium. The devices of the former type may be specifically are a Corona  
25 charging device, an electric field forming device of

an ion flow type, and an electric field forming device of the multi-stylus type having a head, in which electrodes are arranged in a predetermined direction. The device of a latter type may be specifically an electric field forming device of the multi-stylus type, in which electrodes are arranged in a predetermined direction, and neighboring control electrodes are arranged close to the electrodes.

10 [0134] The stirring device may be configured as follows:

[0135] Thus, the stirring device may be configured to form an alternating electric field applied to the reversible image display medium.

15 [0136] This device can be utilized if at least one kind of developing particles have the electrically insulating property.

[0137] Also, the stirring device may be configured to form an oscillating magnetic field applied to the reversible image display medium.

20 [0138] This device can be utilized if at least one kind of developing particles contain a magnetic material.

[0139] Further, the stirring device may be configured to emit ultrasonic waves to the

reversible image display medium.

[0140] The stirring device may be configured to apply mechanical vibrations to the reversible image display medium.

5 [0141] The stirring device may be formed of a combination of the foregoing two or more structures.

[0142] The alternating electric field applying device and the oscillating magnetic field applying device can efficiently stir the developer.

10 [0143] As already described, the stirring of the developer (developing particles) improves the amount of charges and the flowability of the developing particles, and thereby can achieve smooth and reliable image display with high quality.

15 [0144] By stirring the developer prior to the image display, the amount of charges of the developing particles is stabilized. This likewise achieves good image display. Further, the allowable ranges of the chargeability and flowability of the developer can be widened.

20 [0145] For the image display using the reversible image display medium either with or without the electrode, the developer may be stirred also for the purpose of performing the foregoing image erasing  
25 processing, or independently of the image erasing

processing.

[0146] When using the image display medium without an electrode or with an electrode on only one of the substrates, for example, the electrostatic latent image corresponding to the image to be displayed may be formed, e.g., on the surface (substrate surface) of the image display medium, and the electrostatic field may be formed based on the electrostatic latent image simultaneously with or after the formation of the electrostatic latent image, and the developer may be stirred, for example, simultaneously with and/or before formation of the electrostatic field.

[0147] For the image display medium provided with the opposite electrodes, a voltage may be applied across the opposite electrodes to form the electrostatic field, and the developer may be stirred before or simultaneously with the formation of the electrostatic field.

[0148] Regardless of whether the electrode is employed or not, the developer can be stirred, e.g., by a stirring device, which is opposed to an image display medium transporting path, and is located in or upstream to the region for forming the electrostatic field by the electric field formation

device in the relative transporting direction of the image display medium with respect to the electric field formation device.

[0149] The developer stirring device and method

5 may be the same as or similar to those already exemplified in connection with the image erasing processing.

[0150] By stirring the developer for the image display, the contrast can be further improved, and  
10 the drive voltage can be further lowered.

[0151] For the image display employing the reversible image display medium, the electrostatic latent image may be formed on the surface (substrate surface) of the image display medium in such a  
15 manner that the medium surface is uniformly charged to carry the predetermined potential before formation of the electrostatic latent image, and the electrostatic latent image in accordance with the image to be displayed is formed on the charged  
20 region. Based on the electrostatic latent image, the predetermined electrostatic field is formed in accordance with the image to be displayed. Thereby, the developing particles may be moved for the image display.

25 [0152] The formation of electrostatic latent image





image is written onto the charged region, whereby the image holding properties are improved. Particularly, in the case of using the developer having high flowability or the developer having the flowability which can be increased by the developer stirring operation prior to the image display, the advantages relating to the image holding can be achieved. Owing to the above, images of good contrast and high quality can be stably displayed for a long time.

[0155] According to the various reversible image display mediums described above, the images of good contrast, high resolution and high quality can be stably displayed for a long time. Further, remaining of last images can be suppressed, and therefore good reversibility can be achieved. These improve the quality of the displayed image. The image display can be quickly performed with lower drive voltage. The image display can be performed with fewer irregularities.

[0156] Specific examples of the reversible image display medium, image display method and image forming apparatus will now be described below with reference to the drawings.

<Reversible Image Display Medium>

Reversible image display medium 11

[0157] Figs. 1 and 2 show an example of the reversible image display medium. A medium 11 shown in Figs. 1 and 2 includes first and second

5 substrates 111 and 112. These substrates 111 and 112 are opposed to each other with a predetermined gap therebetween. A partition member 113 is arranged between the substrates 111 and 112 for keeping a predetermined gap between the substrates. The  
10 partition member 113 serves also as a spacer between the substrates 111 and 112. The partition member 113 couples and fixes the substrates 111 and 112 together.

[0158] The first substrate 111 is formed of a  
15 light-transparent plate such as a glass plate, a transparent resin film or the like. The substrate 111 is located on the image observation side.

[0159] The external surface of the substrate 111 on the image observation side has a surface average  
20 median roughness Ra of 0.2  $\mu\text{m}$  to 0.7  $\mu\text{m}$ .

[0160] The partition member 113 is also a group of partition walls forming developer accommodating cells (see Fig.3). The partition member 113 is arranged on the inner surface of the first substrate  
25 111 and has a grid-like form as shown in Fig. 3.

[0161] A first electrode 114 is a transparent electrode, and formed on the inner surface of the first substrate 111 opposed to the second substrate 112. The first electrode 114 includes a plurality of independent electrodes 114a arranged in a grid-like form. Each of the independent electrodes 114a is transparent and made of, e.g., indium tin oxide (ITO). The independent electrodes 114a are arranged in cells 116, respectively, with a distance between the neighboring independent electrodes, which is substantially identical with the partition wall thickness  $\alpha$ . Thus one cell corresponds to one pixel.

[0162] The second substrate 112 is not essentially  
20 required to be transparent, but is formed of a  
light-transparent plate such as a glass plate, a  
resin film or the like in this embodiment.

[0163] The second substrate 112 is provided at its inner surface opposed to the first substrate 111 with a second electrode 115. The second electrode

115 in this example extends continuously throughout an image display region of the inner surface of the substrate. The second electrode 115 is not essentially required to be transparent, but may be  
5 formed of, e.g., transparent ITO.

[0164] Each cell accommodates the dry developer DL including the white and black developing particles WP and BP, which are mutually and frictionally charged.

10 [0165] Each cell is sealed so that the developer DL does not leak from the cell.

[0166] The independent electrode 114a forming the second electrode 114 in the image display medium 11 is connected to or provided with a lead portion 110  
15 as shown in Fig.4, and is connected to an electrode select circuit 117 through the lead portion as shown in Fig. 1. The electrode select circuit 117 is connected to a positive drive voltage generating circuit 118a, a negative drive voltage generating  
20 circuit 118b and a display data control portion 119. Each independent electrode 114a is independently supplied with a drive voltage from the electrode select circuit 117. The display data control portion 119 receives display data from display data output  
25 means (not shown) such as a computer, a word

processor, a facsimile machine or the like, and controls the electrode select circuit 117 based on the supplied data. In other words, these electrode select circuit and others form an example of the electric field forming device or the image forming apparatus for the reversible image display medium provided with the electrodes.

[0167] For example, the second electrode 115 in the image display medium 11 is grounded, or a bias voltage is applied from a bias source (not shown) to the electrode 115, if necessary, and the positive or negative drive voltage generating circuit 118a or 118b applies the predetermined voltage across the electrode 115 and each independent electrode 114a via the electrode select circuit 117, which is controlled to perform the desired image display by the display data control portion 119. Thereby, the predetermined electric field is formed for each pixel so that the developing particles WP and BP, which are mixed in the developer DL as shown in Fig. 1, move in accordance with the respective electric fields as shown in Fig. 2. In this manner, the image can be displayed in predetermined contrast. For example, image display can be performed as shown in Fig. 5. In Fig. 5, Bk indicates a portion displayed

[0168] A roller R2 shown with a chain line in Fig.2 will be described later.

Reversible image display mediums 12, 12'

5 [0169] Fig.6(A) and Fig.6(B) show other examples of the reversible image display medium.

[0170] The reversible image display medium 12 shown in Fig.6(A) is identical with the medium 11 of Fig.1 if the medium 11 is such that at least the first substrate 111 is formed of a material having a light transmitting property and an insulating property and that the independent electrodes 114a are not provided.

[0171] The developer-facing internal surface  
15 (internal surface facing the developing particles)  
of the substrate 111 on the image observation side  
has a surface resistivity of at least  $1 \times 10^{12}$   
ohm/square and a surface average median roughness Ra  
of 0.2  $\mu\text{m}$  to 0.5  $\mu\text{m}$ .

20 [0172] The external surface of the substrate 111  
on the image observation side has a surface average  
median roughness Ra of 0.2  $\mu\text{m}$  to 0.7  $\mu\text{m}$ .

[0173] The medium 12 is identical in other respects with the medium 11 of Fig.1. In Fig.6(A),  
25 the same components and parts as in the medium 11

are indicated with the same reference symbols.

[0174] The reversible image display medium 12' shown in Fig.6(B) is identical with the medium 11 of Fig.1 if the medium 11 is such that at least the second substrate 112 is formed of a material having a light transmitting property and an insulating property and that the electrode 115 is not provided. The medium 12' has the substrate 112 on the image observation side.

[0175] The internal surface, which faces the developer DL, of the substrate 112 on the image observation side has a surface resistivity of at least  $1 \times 10^{12}$  ohm/square and a surface average median roughness Ra of 0.2  $\mu\text{m}$  to 0.5  $\mu\text{m}$ .

[0176] The external surface of the substrate 112 on the image observation side has a surface average median roughness Ra of 0.2  $\mu\text{m}$  to 0.7  $\mu\text{m}$ .

The medium 12' is identical in other respects with the medium 11 of Fig.1. In Fig.6(B), the same components and parts as the medium 11 are indicated with the same reference symbols.

[0177] In the medium 12 (or the medium 12'), for example, the electrode 115 of the second substrate 112 (electrodes 114a in the medium 12') is (are)

grounded. In addition, for example, over the

external surface of the first substrate 111 (second substrate 112 in the medium 12'), a) an electrode or electrodes are provided to selectively apply a voltage corresponding to the image to be formed  
5 between the electrode(s) and the ground electrode(s), b) an electrostatic latent image corresponding to the image to be formed is directly formed, or c) an image carrier carrying the electrostatic latent image corresponding to the image to be formed is  
10 contacted (or made to come close), whereby the electric field for driving the developing particles is applied to the developer DL, whereby an image can be displayed.

[0178] The electrode 115 of the medium 12 and the  
15 electrodes 114a of the medium 12' may be electrode(s) having an intermediate resistance value.  
Reversible image display medium 13

[0179] Fig.7(A) shows another example of the reversible image display medium.

20 [0180] The reversible image display medium 13 shown in Fig.7(A) is identical with the medium 11 of Fig.1 if the medium 11 is such that at least the first substrate 111 is formed of a material having a light transmitting property and an insulating  
25 property and that the first substrate electrode 114



and the second substrate electrode 115 are not provided.

[0181] The developer-facing internal surface of the substrate 111 on the image observation side has a surface resistivity of at least  $1 \times 10^{12}$  ohm/square and the developer-facing internal surface of the substrate 112 on the opposed side has a surface resistivity of  $1 \times 10^6$  ohm/square to  $1 \times 10^{12}$  ohm/square.

[0182] The developer-facing internal surface of at least the substrate 111 among the substrates 111, 112 has a surface average median roughness Ra of 0.2  $\mu\text{m}$  to 0.5  $\mu\text{m}$ .

[0183] The external surface of the substrate 111 on the image observation side has a surface average median roughness Ra of 0.2  $\mu\text{m}$  to 0.7  $\mu\text{m}$ .

[0184] The medium 13 is identical in other respects with the medium 11 of Fig.1. In Fig.7(A), the same components and parts as in the medium 11 are indicated with the same reference symbols.

Reversible image display medium 14

[0185] Fig.8(A) shows a further example of the reversible image display medium.

[0186] The reversible image display medium 14

shown in Fig.8(A) is identical with the medium 11 of

Fig.1 if the medium 11 is such that at least the first substrate 111 is formed of a material having a light transmitting property and an insulating property, that the first substrate electrode 114 and the second substrate electrode 115 are not provided, and that a partition member 113 is provided which consists of a plurality of partition walls 113a extending in parallel with the lengthwise side of the medium 14 instead of the grid-like partition member (see Fig.9). The developer-accommodating cell 116 is provided between the neighboring partition walls 113a. Each cell 116 accommodates the developer DL containing mutually frictionally charged white developing particles WP and black developing particles BP.

[0187] In the periphery of the medium 14, the two substrates 111, 112 are heat-sealed to form a sealing portion 140. The part 140a of the sealing portion 140 is provided at the both ends of the longitudinal partition walls 113a extending in the lengthwise direction, and serves also as the partition wall forming the cell 116.

[0188] As shown in Fig.9, the partition walls 113a are formed with a width  $\alpha$ , a height  $h$  and a space  $pt$  between the adjacent partition walls 113a.



potential, if necessary.

Reversible image display mediums 15, 15'

[0193] Fig.10(A) and Fig.10(B) show further examples of the reversible image display medium.

5 [0194] The reversible image display medium 15 (15') shown in Fig.10 (A) (Fig.10(B)) is identical with the medium 13 (14) except that an electrically conductive film 112A is formed on an outer surface of the second substrate 112 in the medium 13 (14).

10 [0195] In respect of the mediums 15, 15', the internal surface of the substrate 111 on the image observation side, which faces the developer DL, has a surface resistivity of at least  $1 \times 10^{12}$  ohm/square and the internal surface of the substrate 112 on the

15 opposed side, which faces the developer DL, has a surface resistivity of  $1 \times 10^6$  ohm/square to  $1 \times 10^{12}$  ohm/square.

[0196] The internal surface of at least the substrate 111, which faces the developer DL, among

20 the substrates 111, 112 has a surface average median roughness Ra of  $0.2 \mu\text{m}$  to  $0.5 \mu\text{m}$ .

[0197] The external surface of the substrate 111 on the image observation side has a surface average median roughness Ra of  $0.2 \mu\text{m}$  to  $0.7 \mu\text{m}$ .

25 [0198] The medium 15 (15') is identical in other

respects with the medium 13 (14). In Fig.10(A) and Fig.10(B), the same components and parts as in the medium 13 (14) are indicated with the same reference symbols.

5 [0199] In image display by the mediums 15, 15', for example, the electrically conductive film 112A is set to a ground potential or like proper potential, and a) an electrostatic latent image corresponding to the image to be formed is directly  
10 formed on the first substrate 111, or b) an image carrier carrying the electrostatic latent image corresponding to the image to be formed is contacted with (or made close to) the first substrate 111, whereby an image can be displayed by application of  
15 electric field for driving the developing particles to the developer DL.

[0200] Optionally the second substrate 112 may be made electrically conductive by dispersing an electrically conductive material, instead of  
20 provision of the electrically conductive film 112A and may be set to a ground potential or like proper potential.

[0201] Each of the image display mediums already described with reference to the drawings and the  
25 image display method utilizing the mediums can

repeat the image display and image erasure.

[0202] The developing particles WP and BP are contained in the cell, and it is not necessary to supply externally the developer into the cell.

5 Thereby, it is possible to suppress significantly the use of medium such as paper sheets and consumable materials such as developer, which are required for image display in the prior art. Since a heat energy for melting and fixing the toner onto  
10 the medium is not required in contrast to the conventional image display, the image forming energy can be reduced. Accordingly, it is possible to satisfy the present demand for reduction in environmental loads.

15 [0203] Since each of the mediums 11 to 15' employs the dry developer DL including developing particles WP and BP of different colors, one kind of the developing particles WP (or BP) can hide the other kind of developing particles BP (or WP) to a higher  
20 extent so that the image display in higher contrast can be achieved.

[0204] The developing particles WP and BP accommodated in the cell are charged to the different polarities, respectively, and therefore  
25 can be easily moved for image display by the Coulomb

force applied thereto. This also improves the contrast for image display, and can suppress remaining of the last image. Further, the image display can be quickly performed, and the drive voltage for image display can be lowered.

[0205] Further, employment of the dry developer DL can suppress settling and condensation of the developing particles so that lowering in contrast for the image display can be suppressed, and the image display can be stably performed for a long time. Since the settling and condensation of the developing particles are suppressed, remaining of the last displayed image can be suppressed. Since the change in quality with time is suppressed in the dry developer DL, this also allows stable image display for a long time.

[0206] When images are displayed by forming an electrostatic latent image on the substrate 111 (112) on the image observation side which is not provided with any internal electrode in the medium 12 (12'), the internal surface of the substrate 111 (112) of the medium 12 (12'), which faces the developer DL, has a surface resistivity of at least  $1 \times 10^{12}$  ohm/square so that the electrostatic latent image formed on the substrate can be firmly held and

high quality images can be displayed.

[0207] The internal surface of the substrate 111 (112) on the image observation side which is not provided with any internal electrode in the medium 12 (12') has a surface average median roughness Ra of 0.2  $\mu\text{m}$  to 0.5  $\mu\text{m}$ . Therefore, it is possible to suppress the unneeded firm adherence of the developing particles to the substrate and to control the occurrence of remaining images, allowing display of high quality images.

[0208] When images are displayed by forming an electrostatic latent image on the substrate 111 on the image observation side which is not provided with any internal electrode in the mediums 13, 14, 15 and 15', the internal surface of the substrate 111 of the medium 13, 14, 15 and 15' which surface faces the developing particles has a surface resistivity of at least  $1 \times 10^{12}$  ohm/square so that the electrostatic latent image formed on the substrate can be firmly held. Further, since the internal surface of the substrate 112 which surface faces the developer DL has a surface resistivity of  $1 \times 10^6$  ohm/square to  $1 \times 10^{12}$  ohm/square, the images displayed in the case of mediums being overlapped can be stably retained, and remaining of last images



is suppressed in erasure of images and in rewriting thereof, resulting in suppressed image irregularity. Thereby high quality images can be displayed.

[0209] The developer-facing internal surface of at

5 least the substrate 111 among the substrates 111 and 112 which is not provided with any internal electrode in the mediums 13, 14, 15 and 15' has a surface average median roughness Ra of 0.2  $\mu\text{m}$  to 0.5  $\mu\text{m}$ . Therefore, it is possible to suppress the  
10 unneeded adherence of the developing particles to the substrate and to control the occurrence of remaining images, allowing display of high quality images.

[0210] The external surface of the substrate on

15 the image observation side in any of the mediums 11 to 15' has a surface average median roughness Ra of 0.2  $\mu\text{m}$  to 0.7  $\mu\text{m}$ , resulting, when the displayed image is seen, in controlled light quantity of regular reflection (gloss) and suppressed scattering  
20 of light, and displayed image in good contrast can be easily seen.

[0211] Any one of the mediums 11 to 15' can display images in high resolution as compared with the conventional electrophoretic display.

25 [0212] The mediums except for the medium 11 can

display images in higher resolution as compared with the medium 11 in which the resolution is affected by the size of the pixel electrodes 114a.

[0213] Now, description is given below on

5 examples of image display operation using mediums 12, 12', 13, 14, 15 and 15', as well as on image forming apparatuses.

[0214] The image forming apparatus shown in Fig.11 includes a photosensitive drum PC which is driven to rotate in the direction of an arrow in the drawing. Provided around the photosensitive drum PC are a scorotron charger CH, a laser image exposing device EX, and an eraser lamp IR. The electrode roller R1 which is driven to rotate is provided under the drum  
10 PC. The electrode roller R1 is a developing electrode roller for forming an electrostatic field for image display. The electrode roller R1 can be supplied with a bias voltage from the power source PW1 and may be internally provided with a rotary  
15 magnetic pole roller R2 which is driven to rotate in a direction opposite to that of the roller R1 (or which is driven to rotate reciprocatingly).

[0215] After the surface of the drum PC is charged by the charger CH, image exposure is performed on the  
25 charged region by the laser image exposing device EX



charges on the surface of the photosensitive drum PC are erased by the eraser lamp IR to make ready for the next printing.

5 [0219] It is not essential that the surface of the medium 13 (14) be charged by the charger CRH.

[0220] When the developer DL contains magnetic developing particles in image display, e.g. black developing particles BP are magnetic, the magnetic pole roller R2 is provided and rotated whereby the  
10 developer DL in the cells 116 is stirred and the developing particles BP, WP become easily movable to accomplish display of better images with lower drive voltage.

[0221] If the developer DL contains magnetic  
15 developing particles in the medium 11 shown in Figs.1 and 2, the rotary magnetic pole roller R2 is usable as indicated with a chain line in Fig.2.

[0222] Optionally, a magnet plate MG with alternately arranged S and N magnetic poles may be  
20 provided downstream in a medium feed path as shown with a chain line in Fig.11 instead of the rotary magnetic pole roller R2.

[0223] Using the mediums 12, 12' or the mediums 15, 15', image display can be also achieved by this  
25 image forming apparatus. When images are displayed

on the medium 12, 12', 15 or 15', the following electrodes or the like may be grounded or supplied with a bias voltage: the second electrode 115 in the medium 12, the pixel electrodes 114a in the medium 12' and the electrically conductive film 112A in the mediums 15, 15'.

[0224] The image forming apparatus shown in Fig. 12(A) includes a direct electrostatic latent image forming device CR2 of an ion flow type. The device CR2 includes a corona ion generating portion c2 for generating corona ions, a write electrode e2 for leading the corona ions generated by the ion generating portion onto the surface of, e.g., the first substrate 111 in the medium 13 (or 14), a write electrode control circuit f2 for applying to the write electrode e2 the voltage, which is used for leading the positive or negative corona ions to the pixel corresponding portion on the surface of the substrate 111 in accordance with the image to be displayed..

[0225] The corona ion generating portion c2 includes a shield casing c21 and a corona wire c22, which is stretched in the casing c21. The corona wire c22 is formed of, e.g., gold-plated tungsten wire of 60  $\mu\text{m}$  to 120  $\mu\text{m}$  in diameter. A power source



write electrode e2, and is supplied with a positive bias voltage from the power source PW1 or the roller R1 is grounded. The roller R1 is internally provided with a magnetic pole roller R2, which is driven to rotate.

[0230] The surface of the medium 13 (or 14) is uniformly charged to a predetermined potential by a charger such as corona charger and the charged medium 13 (14) is moved relatively to the device CR2.

At the same time, the electrode roller R1 is driven to rotate in the medium feed direction, and the magnetic pole roller R2 is rotated in the opposite direction. In accordance with the instruction by the control portion f21, positive corona ions are led to the predetermined pixel corresponding portion corresponding to the image to be displayed among the plurality of pixel corresponding portions on the surface of the first substrate 111, as shown in Fig. 12(A), and outflow of the ions are prevented for the other pixels as shown in Fig.12(B). Thus the image display on the medium 13 (or 14) can be performed as shown in Figs.7(B) and 8(B).

[0231] It is not essential that the surface of the medium 13 (or 14) is previously charged. The discharging wire c22 in the device CR2 may be

replaced with solid discharging elements.

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[0232] Using the mediums 12, 12' or the mediums 15, 15', image display can be achieved by this image forming apparatus. When images are displayed on  
5 these medium 12, 12', 15 or 15', the following electrodes or the like may be used instead of the electrode roller R1 and may be grounded or supplied with a bias voltage: the second electrode 115 in the medium 12, the pixel electrodes 114a in the medium  
10 12' and the electrically conductive film 112A in the mediums 15, 15'.

[0233] The electrostatic latent image forming device CR2 shown in Fig. 12(A) utilizes the discharging phenomenon. Instead of it, electrostatic  
15 latent image forming devices of various discharging types other than the above may be utilized.

[0234] The image forming apparatus shown in Fig. 13 includes a direct electrostatic latent image forming device CR3 of the multi-stylus type. The  
20 device CR3 includes a multi-stylus head H3 having a plurality of electrodes e3, which are arranged in the main scanning direction of, e.g., medium 15 (or 15'), and are arranged close to the first substrate 111. A signal voltage is applied to each electrode  
25 e3 for applying electrostatic latent image charges





control electrodes e41 are arranged close to the  
record electrodes e4. This head is located, e.g.,  
near the medium, and the control electrodes e41 of  
the head H4 are successively and sequentially  
5 supplied with a voltage nearly equal to half the  
voltage (record voltage) required for the image  
recording. Also, the record electrodes e4 are  
supplied with the image signal voltage nearly equal  
to half the record voltage. Thereby, the  
10 electrostatic latent image can be formed on the  
medium located immediately under the record  
electrode.

[0238] Now, description is given below to specific  
examples of developing particles and developer, and  
15 to specific examples of the reversible image display  
medium and experimental examples using the image  
display mediums.

[I] Examples of adjustment of surface resistivity  
and surface roughness of substrate surface facing  
20 the developer

<Developing particles and developer>

White developing particles WP

[0239] In a Henschel mixer were thoroughly mixed  
100 parts by weight of thermoplastic polyester resin  
25 (softening point: 121°C, Tg: 67°C), 40 parts by

5 mixture was further mixed by a twin-screw extruder and then cooled. The mixture was roughly pulverized, then pulverized by a jet mill and classified with wind to obtain white fine powders which have volume average particle size of 10.1  $\mu\text{m}$ .

10    [0240]    To the white fine powders having the above  
size was added 0.3 parts by weight of hydrophobic  
silica particles (Nihon Aerosil Co., Ltd.: Aerosil  
R-972). The mixture was mixed by a Henschel mixer to  
prepare white developing particles.

15 Black developing particles BP

[0241] In a Henschel mixer were thoroughly mixed 100 parts by weight of styrene-n-butyl methacrylate resin (softening point: 132°C, Tg: 65°C), 2 parts by weight of carbon black (Lion Oil & Fat Co., Ltd.: Ketchen Black), 1.5 parts by weight of silica (Nihon Aerosil Co., Ltd.: # 200) and 500 parts by weight of magnetic powder containing magnetite (RB-BL, Titan Kogyo Co., Ltd.). The mixture was further mixed by a kneader.

25 [0242] After cooling, the mixture was roughly

pulverized by a feather mill, then finely pulverized by a jet mill and classified with wind to obtain black particles BP which have a volume average particle size of 25  $\mu\text{m}$ .

5 Preparation of Developer DL

[0243] The white particles WP (30 g) and the black particles BP (70 g) were placed into a polyethylene bottle. The bottle was rotated by a ball mill pedestal to perform kneading and mixing for 30 minutes to obtain developer DL. The white developing particles WP were negatively charged and black developing particles BP were positively charged in the developer.

<Reversible image display medium D1>

15 [0244] The reversible image display medium D1 is of the same type as the medium 13 shown in Fig.7(A) and was prepared as follows.

[0245] A film of UV-curing resin of 100  $\mu\text{m}$  thickness was brought close to the first substrate 111 formed of a transparent PET (polyethylene terephthalate) film of 25  $\mu\text{m}$  thickness. Over the UV-curing resin film was laid a photomask opened in a specified pattern. The top of the photomask was irradiated with UV rays, followed by development and washing. A grid-like partition member 113 was formed



instead of sealing with the epoxy resin adhesive  
119b as shown in Fig.7(A).

[0250] In this way, a medium D1 of the type shown  
in Fig.7(A) was produced.

5 <Reversible image display mediums D2 to D11>

Reversible image display mediums D2 to D11 are of  
the same type as the reversible image display medium  
D1. They are different from each other in surface  
resistivity of the developer-facing internal surface  
10 of the substrate 111 on the side for forming an  
electrostatic latent image, or they are further  
different from each other in surface resistivity of  
the developer-facing internal surface of the  
substrate 112 on the opposed side.

15 <Reversible image display mediums D12 to D15>

[0251] Reversible image display mediums D12 to D15  
are of the same type as the reversible image display  
medium D1. They are different from each other in  
surface roughness of the developer-facing internal  
20 surface of the substrate 111. Different degrees of  
surface roughness were created by blasting or heat-  
press embossing or otherwise.

[0252] Table 1 shows the surface resistivity of  
the developer-facing surface of the substrate 111 or  
25 112 in each medium, and the surface roughness Ra of

the developer-facing surface of the substrate 111 in each medium.

[0253] In any of mediums D1 to D15, the developer-facing surface of the substrate 112 had a surface

5 roughness Ra of 0.25  $\mu\text{m}$ .

**Table 1**

medium	substrate 111		opposite substrate 112
	surface resistivity $\Omega/\square$	surface roughness Ra $\mu\text{m}$	surface resistivity $\Omega/\square$
D1	$1.20 \times 10^{15}$	0.25	$3.50 \times 10^5$
D2	$1.20 \times 10^{15}$	0.25	$4.20 \times 10^6$
D3	$1.20 \times 10^{15}$	0.25	$1.50 \times 10^9$
D4	$1.20 \times 10^{15}$	0.25	$2.20 \times 10^{11}$
D5	$1.20 \times 10^{15}$	0.25	$5.10 \times 10^{12}$
D6	$1.20 \times 10^{15}$	0.25	$3.20 \times 10^{13}$
D7	$1.20 \times 10^{15}$	0.25	$1.20 \times 10^{15}$
D8	$2.30 \times 10^{13}$	0.25	$1.50 \times 10^9$
D9	$2.20 \times 10^{12}$	0.25	$1.50 \times 10^9$
D10	$4.70 \times 10^{11}$	0.25	$1.50 \times 10^9$
D11	$5.70 \times 10^9$	0.25	$1.50 \times 10^9$
D12	$1.20 \times 10^{15}$	0.16	$1.50 \times 10^9$
D13	$1.20 \times 10^{15}$	0.52	$1.50 \times 10^9$
D14	$1.20 \times 10^{15}$	0.68	$1.50 \times 10^9$
D15	$1.20 \times 10^{15}$	0.85	$1.50 \times 10^9$

[0254] Image display was performed using any of the mediums D1 to D15 by the image forming apparatus

10 including the ion flow type direct electrostatic latent image forming device CR2 as shown in Fig.12(A) and Fig.12(B).

[0255] The surface of the first substrate 111 was uniformly charged by a corona charger (not shown) to

carry a negative polarity potential (-500 V). The second substrate 112 of the charged medium was set to a ground potential. Then, positive corona ions were led to the predetermined pixel corresponding portions

5 corresponding to the image to be displayed among the plurality of pixel corresponding portions on the surface of the first substrate 111 of the medium. The portions were charged to carry a positive polarity potential (+500 V) and to carry the same

10 potential in terms of absolute value as the above negatively charged potential (-500 V). For the other pixels, only a bias potential (ground potential here) was applied. Thereby the positive corona ion-charged portions and the non-charged portions were charged to

15 carry the same potential (500 V) in terms of absolute value and to give different polarities. Thus, image display was conducted such that the positive corona ion-loaded portions were displayed in white by negatively charged white developing particles WP and

20 the positive corona ion-unloaded portions were displayed in black by positively charged black developing particles BP.

[0256] In image display, the magnetic pole roller R2 was rotated to apply a stirring force to the

25 developing particles in the medium, whereby images



were smoothly displayed.

[0257] Using each of the mediums D1 to D15, image display was performed to evaluate the contrast of displayed images, and to evaluate the initial images, 5 the images after repeated image display, and the image stability after repeated image display (suppressed remaining of last images).

[0258] The contrast was evaluated in terms of an average image density which was obtained by measuring 10 the image density (Bk density) of the black portion and the image density (W density) of the white portion by a reflection densitometer (product of Konica Corporation, Sakura DENSITMETER PDA-65). The average density ratio (Bk av./W av.) of 5.0 or more 15 was rated as good (O) and that of less than 5.0 as poor (X).

[0259] The image stability after repeated image display was evaluated by comparing the average image density of initially displayed images with the 20 average image density of the images (50<sup>th</sup> images) after repeated image display (after 49 times repetition). When the change of average image density between the initially displayed images and repeatedly displayed images (50 times repetition) was 25 0.2 or less, it was rated as good (O). The value of

more than 0.2 was rated as not good (X).

[0260] The surface resistivity was measured in an environment of 65%RH according to ASTM D-257.

[0261] The surface average median roughness Ra of  
5 the substrate was measured using a surface roughness  
measuring instrument (Surfcom 554A manufactured by  
Tokyo Seimitsu Co., Ltd.) and Pick-up E-DT-S02A for  
measuring the roughness of soft materials.

[0262] The image evaluation results are shown in  
10 Table 2.

Table 2

	initial image				50th image after 49 times repetition				initial		image		image stability evaluation ③-⑤
	black portion		white portion		black portion		white portion		contrast Bk av/W av, ③/⑥	image irregularity Bkmax-Bkmin, ①-②	contrast 8k av/W av, ⑨/⑫	image irregularity Bkmax-Bkmin, ⑦-⑩	
	density ①	mean ②	density ③	mean ④	density ⑤	mean ⑥	density ⑦	mean ⑧					
medium	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬
D1	1.43	0.85	1.14	0.80	0.55	0.68	1.20	0.70	0.95	0.75	0.52	0.64	0.19
D2	1.48	1.32	1.40	0.32	0.22	0.27	1.42	1.30	1.36	0.32	0.22	0.27	0.04
D3	1.61	1.52	1.57	0.28	0.23	0.26	1.59	1.52	1.56	0.30	0.23	0.27	0.01
D4	1.66	1.61	1.64	0.26	0.22	0.24	1.59	1.50	1.55	0.32	0.24	0.28	0.09
D5	1.65	1.54	1.60	0.26	0.24	0.25	1.52	1.48	1.50	0.30	0.25	0.28	0.10
D6	1.60	1.42	1.51	0.24	0.20	0.22	1.30	1.15	1.23	0.35	0.28	0.32	0.29
D7	1.61	1.44	1.53	0.32	0.23	0.28	1.35	1.20	1.28	0.45	0.30	0.38	0.25
D8	1.48	1.29	1.38	0.28	0.24	0.26	1.43	1.29	1.36	0.28	0.24	0.26	0.03
D9	1.43	1.25	1.34	0.30	0.23	0.27	1.43	1.25	1.34	0.30	0.23	0.27	0.00
D10	1.42	1.25	1.34	0.30	0.23	0.27	1.43	1.25	1.34	0.30	0.23	0.27	0.00
D11	1.33	1.15	1.24	0.42	0.32	0.37	1.25	1.15	1.20	0.42	0.32	0.37	0.04
D12	1.61	1.46	1.54	0.32	0.24	0.28	1.40	1.25	1.33	0.45	0.28	0.37	0.21
D13	1.62	1.46	1.54	0.30	0.23	0.27	1.62	1.46	1.54	0.31	0.25	0.28	0.00
D14	1.60	1.50	1.55	0.35	0.25	0.29	1.40	1.28	1.34	0.48	0.30	0.39	0.02
D15	1.58	1.45	1.52	0.33	0.25	0.29	1.32	1.16	1.24	0.55	0.38	0.47	0.28

[0263] As apparent from Table 2, when image display is performed by forming an electrostatic latent image, it is suitable that the developer-facing surface of the substrate for carrying the electrostatic latent image has a surface resistivity of at least  $1 \times 10^{12}$  ohm/square. On the other hand, it is suitable that the developer-facing surface of the opposed substrate has a surface resistivity of  $1 \times 10^6$  ohm/square to  $1 \times 10^{12}$  ohm/square.

[0264] The same can be mentioned about the image display mediums of the same type as the mediums 14, 15 and 15'.

[0265] As also apparent from table 2, the surface of at least one of the substrates, especially the developer-facing surface of the substrate on the image observation side, has suitably a surface roughness in terms of a surface average median roughness Ra in a range of  $0.2 \mu\text{m}$  to  $0.5 \mu\text{m}$ .

[0266] The same can be mentioned about the image display mediums of the same type as the mediums 12, 12', 14, 15 and 15'.

[II] Examples of adjustment of surface roughness of external surface of substrate on the image observation side

<Developing particles and developer>

[0267] The same developing particles and developer as used in the experiments in foregoing [I] descriptive portion were employed.

<Reversible image display mediums D1' to D9'>

5 [0268] Reversible image display mediums D1'to D9'are of the same type as the reversible image display medium 13 shown in Fig.7(A), and were prepared as follows.

[0269] A plurality of transparent PET  
10 (polyethylene terephthalate) films of 25  $\mu$ m thickness were provided. A thermoplastic transparent resin was uniformly applied to one surface of each film. On the resin layer was laid a sheet for forming a shape, which was used for obtaining  
15 different surface roughness degrees. The sheet was pressed on the resin layer with heating. The press processing was conducted at 80°C and 10 kg/cm<sup>2</sup> for 30 minutes.

[0270] After cooling, the shape-forming sheet was  
20 peeled off to give a first substrate 111 on the image observation side (side for forming an electrostatic latent image) in which the external surface had controlled surface average median roughness.

[0271] A film of UV-curing resin of 100  $\mu$ m  
25 thickness was brought close to the surface roughness-

noncontrolled internal surface of the substrate 111 on the image observation side. Over the resin film was laid a photomask opened in a specified pattern. The top of the photomask was irradiated with UV rays, followed by development and washing. A grid-like partition member 113 was formed on the substrate 111 (see Fig.3). Partition walls 113a forming the partition member 113 had a thickness (width)  $\alpha$  (50  $\mu\text{m}$ ), a height  $h$  (100  $\mu\text{m}$ ), and a wall space  $pt$  (1 mm).

10 [0272] Then, the developer DL was placed into each cavity surrounded with the partition wall of the grid-like partition member 113 of the first substrate 111. The volume proportion of the developer placed into the cavity was 30% based on 15 the volume of the cavity.

[0273] A photo-curing adhesive 119a (see Fig.7(A)) was applied to a small thickness only to the top of the partition member 113 on the substrate 111. Thereafter the second substrate 112 formed of a 20 transparent PET film of 25  $\mu\text{m}$  thickness containing carbon black was closely laid on the adhesive, followed by curing the adhesive by UV irradiation to adhere the film.

[0274] Thereafter, the peripheries of the first 25 and second substrates 111, 112 were heat-sealed

instead of sealing with the epoxy resin adhesive  
119b as shown in Fig.7(A) .

[0275] The procedure gave 9 kinds of mediums D1'  
to D9' of the type shown in Fig.7(A) in which the  
5 external surface of the substrate 111 on the image  
observation side had different surface average  
median roughnesses. Table 3 shows the surface  
average median roughness of the mediums.

[0276] The surface average median roughness Ra was  
10 measured using a surface roughness measuring  
instrument (Surfcom 554A manufactured by Tokyo  
Seimitsu Co., Ltd.) and Pick-up E-DT-S02A for  
measuring the roughness of soft materials.

**Table 3**

medium	external surface of substrate on image observation side
	average median roughness Ra $\mu m$
D1'	0.12
D2'	0.18
D3'	0.21
D4'	0.33
D5'	0.45
D6'	0.62
D7'	0.75
D8'	0.87
D9'	1.05





displayed in white by negatively charged white developing particles WP and the positive corona ion-unloaded portions were displayed in black by positively charged black developing particles BP.

5 [0279] In image display, the magnetic pole roller R2 was rotated to stir the developing particles in the medium, whereby images were smoothly displayed.

[0280] Using the mediums D1' to D9', image display was performed to evaluate the contrast and the gloss on the external surface of the substrate on the image observation side.

10 [0281] The contrast was evaluated in terms of an average image density which is obtained by measuring the image density (Bk density) of the black portion and the image density (W density) of the white portion using a reflection densitometer (product of Konica Corporation, Sakura DENSITMETER PDA-65). The average density ratio (Bk av./W av.) of 5.0 or more was rated as good (○) and that of less than 5.0 as poor (X).

20 [0282] The gloss was measured by a glossimeter (product of Nippon Denshoku Industries Co., Ltd., VG-2000) used at a measuring angle of 20 degrees. The measured value of 40 or less was rated as good (○).  
25 The value of more than 40 was rated as not good (X).

[0283] The image evaluation results are shown in Table 4.

Table 4

medium	gloss		image density		contrast		overall evaluation
	20° measurement	evaluation	black portion average density (B <sub>av</sub> )	white portion average density (W <sub>av</sub> )	Bk av./W av.	evaluation	
D1'	124.0	X	1.62	0.25	6.48	○	X
D2'	58.2	X	1.60	0.26	6.15	○	X
D3'	38.4	○	1.58	0.25	6.32	○	○
D4'	33.4	○	1.60	0.25	6.40	○	○
D5'	28.5	○	1.58	0.24	6.58	○	○
D6'	22.5	○	1.28	0.23	5.57	○	○
D7'	18.4	○	1.08	0.22	4.91	X	X
D8'	12.5	○	0.95	0.23	4.13	X	X
D9'	10.1	○	0.82	0.20	4.10	X	X

5     **[0285]**     As apparent from table 4, it is suitable that the external surface of at least the substrate on the image observation side among the two substrates for forming the medium has a surface average median roughness Ra of 0.2  $\mu\text{m}$  to 0.7  $\mu\text{m}$ .

10   **[0286]**   The same can be mentioned about the image  
display mediums of the same type as the mediums 11,  
12, 12', 14, 15 and 15'.

[0287] Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.